Storytelling with Uniview #13
Cosmology Misconceptions Part II

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In the first part of "Cosmology Misconceptions" in column #10, we went over the evidence for the Big Bang, and reviewed some of the misconceptions that the public may hold that have been uncovered by educational researchers. But it turns out that the inherent nature of some astronomical datasets and how they are used in the Uniview software can almost guarantee problems in their understanding by the public. In this follow-up column, we will look at some of the pitfalls, and how we can avoid spreading—even inadvertently—misconceptions.

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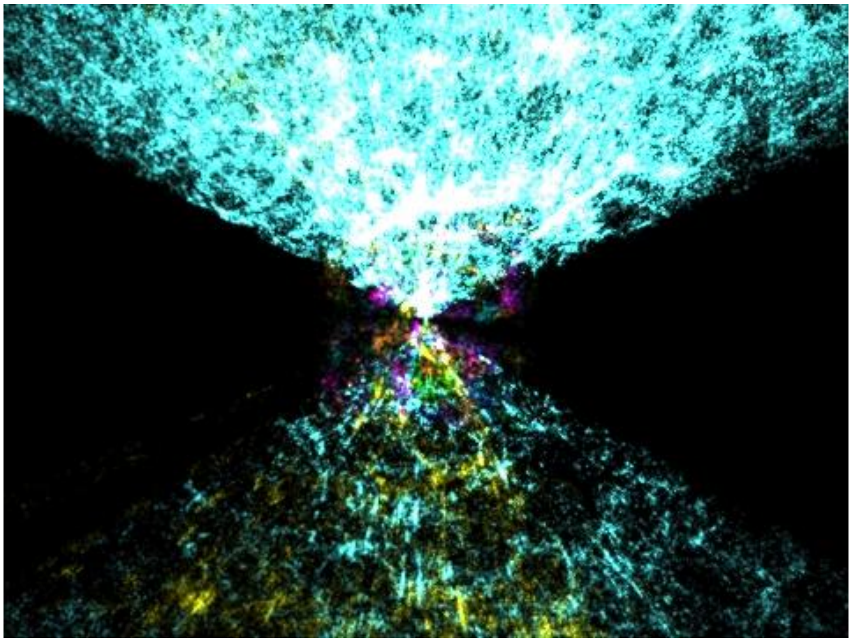
For a novice Uniview pilot, perhaps the first rule of navigation learned is that the virtual camera is attached via an invisible tether to an object (which could be Earth, the Sun, the International Space Station, etc.). The default view is for the camera to be looking down at the object it is tethered to; you have to actively turn the view to avoid looking down. Navigation is either by rotating the virtual camera around its anchor, or translating the camera into or away from the tether point.

With this basic navigational paradigm, it is quite easy to start at Earth (where you begin by default when the software starts up), and zoom out to see increasingly larger volumes of the Universe, from the Solar System to the nearby stars, followed by the entire Milky Way the extragalactic web of galaxies, and finally to the cosmic microwave background. As you do so, the visual experience of this flight may lead to some unexpected conceptual consequences for the visitor.

Returning to the Geocentric Universe

Learning about our place in the Universe is fundamental to all introductory astronomy courses. This lesson usually includes Claudius Ptolemy's 2nd century CE model of the Universe, with Earth at the center, and surrounded by the Moon, Sun, planets, and stars at increasing distances. As more careful observations were collected over time, it was clear that the circular motions in the Ptolemaic model were unable to explain planetary motions, even when corrections to the orbits like "epicycles" and the "equant" were added.

The geocentric model was eventually abandoned and replaced by the heliocentric model, in which Earth became just another planet orbiting the Sun. Nicolaus Copernicus's Sun-centered model is not the first of its type, nor is it the model that is accepted today. Instead Johannes Kepler's explanation of planetary trajectories as ellipses rather than circles is still taught in schools today, along with the deeper explanations brought about by Isaac Newton's (and eventually Albert Einstein's) work. But Copernicus' impact on the intellectual landscape was so enormous that we still talk of the Copernican revolution, even when neither the Sun nor our Milky Way is thought to be at the center of the Universe.[1]



Humans have been removed from the center in our astronomical narrative, but this principle conflicts with the cosmos as depicted by Uniview. Because the virtual camera points back at an anchor point on or near Earth by default, the viewer is given a geocentric view. This geocentricity becomes more pronounced the further away we travel from Earth. Inside the Milky Way Galaxy, the distribution of stars around the Sun is random and spread wide enough that the Sun is not visibly associated with the "center" of the distribution.[2] But if we zoom out far enough to see the Extragalactic→Tully Galaxies, or even further into the Extragalactic→Sloan Galaxies or Extragalactic→2DF Galaxies, it is clear that these extragalactic distributions have the Milky Way (and by implication the Sun and Earth) at their centers. The web of galaxy clusters and superclusters from the Sloan and 2DF surveys form angular geometries that point back towards the Milky Way. The nature of astronomical surveys—which incompletely sample the sky, and which become more and more sparse the further out they look—means that these datasets look intrinsically geocentric when visualized in Uniview.

So if you do zoom out past the Tully collection of galaxies to see the more distant galaxy surveys, make a habit of pointing out to visitors that the surveys are inherently patchy and limited in scope. There are more gaps than there are volumes of space with data, with the gaps showing our inability to sample those regions. If alien astronomers living in a galaxy elsewhere in the Universe were doing similar galaxy survey work, they would see similar distributions centered on their galaxy. The implied geocentricity is an artifact of the data-taking.

Mixing Time and Space

Another confusing aspect of astrophysical datasets in Uniview is that we are not seeing just objects distributed in three-dimensional (3D) space, but objects that are placed in 3D space and in time. Recall that the speed of light is constant, so as we peer deeper into the cosmos, we are also looking back in

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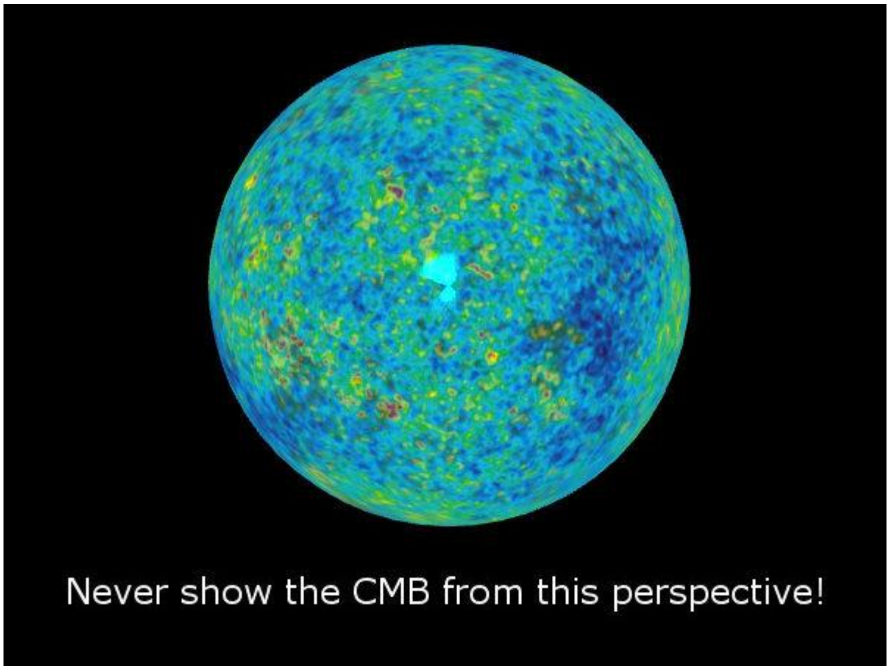
[1] And in fact, in modern cosmology, there is no center to the Universe.

[2] However if we toggle on the constellation lines, the geo/heliocentric nature of the HIPPARCOS star distribution becomes instantly apparent.

time. If you move Uniview's virtual camera through a web of galaxy clusters, you cannot assume that this is their distribution today. Instead the distribution reflects where the galaxies were when their light left on their way to our eyes and instruments. We could extrapolate the 3D positions of the galaxies forward in time assuming a model of expansion for the Universe, which would give a best guess as to where those galaxies are today. But that is not what is shown in Uniview.[3]

Outside the Cosmic Horizon



It is easy to fly the virtual camera outside of the cosmic microwave background (CMB) sphere, since there are no limits to how far you can zoom out. This is a big problem because it brings up two conceptual stumbling blocks for the viewer. First the CMB sphere is centered on the origin where the Milky Way and Sun are located. So just by showing all (or even a good fraction) of the CMB sphere and rotating our camera around it, we are presenting a geocentric view. Second, remember that distance from the observer equals look-back time. The CMB, originating 400,000 years after the Big Bang, is the furthest we can directly probe in the Universe both spatially and temporally. We cannot make direct observations past the CMB—it is effectively a cosmic horizon. Going outside the CMB sphere is unphysical since you are implying that you are observing the radiation from a point in spacetime before the Big Bang, which does not make any sense!

If I wish to talk about the CMB, instead of pulling the camera outside the CMB sphere, I will manually toggle it on well before it turns on automatically, to avoid the misleading visual depiction that the CMB is a physical sphere centered on the Milky Way. I instead focus my presentation on what it means to see relic radiation, streaming from parts of the Universe that are 13.4 billion light years away. The inhomogeneities in the otherwise smooth radiation field eventually lead to the large scale structures that we see in the extragalactic surveys. An alien species, living in a galaxy that evolved from of one of the CMB bumps that we observe from Earth, would see their nearby Universe to be very similar to our view of the Universe, filled with clusters of galaxies. These aliens would see their own version of the CMB radiation around them consisting of light emitted 13.4 billion years ago. If they observe in the sky where the Milky Way is today, they would see merely a ripple in the cosmic background radiation, not the current galaxies that exist today. There hasn't been time for any light from the current Milky Way to reach this alien astronomer.

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[3] To give you a sense of how big of an effect the expansion of the Universe has, the light from the cosmic microwave background (CMB) we observe today left 13.4 billion years ago. However the galaxies that have evolved since from those regions which emitted the CMB radiation are now 45 billion light years away!

Concluding Thoughts

There are a couple of lessons that bear repeating. First many astrophysical datasets have an inherent geocentric bias. This is due to the fact that they are based on observations using telescopes either on Earth or in near Earth orbit; we have better observations for objects close by us, than those further away; and the further we look, the less complete our surveys tend to be. The result is that when we display visualizations of these datasets, we impart a geocentric outlook that we may not wish to give to a visitor.

And even though we see a static collection (at least for outside the Solar System) of celestial bodies distributed in 3D space in Uniview, this view is less and less accurate the further we transport ourselves. Remember that even within our own Solar System, we view the Moon, the Sun, and planets not in the present, but as they were a second, or minutes, or many hours in the past. As we look at objects progressively further away, we see them further back in time. Over the millions or even billions of years of light travel times, we expect not only the appearance of galaxies to change, but their orientations and distances would be radically altered as well, given their gravitational interactions with neighboring galaxies and the expansion of the Universe. So do not think of Uniview as showing a cosmic atlas over space. Instead it’s an atlas of space and time.